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Treatment of High Strength Pharmaceutical and Chemical Industrial Wastewater by Biological treatment

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Abstract

The chemical industry is of importance in terms of its impact on the environment. The wastewaters from this industry are generally strong and may contain toxic parameters. Chemical industrial wastes usually contain organic and inorganic matter in varying degrees of concentration. The best strategy to clean highly contaminated and toxic industrial wastewater is in general to treat them at the source and sometimes by applying onsite treatment within the production lines with recycling of treated effluent. The main objectives of this study to find a sustainable solution for the industrial wastewater in order to comply with the National Regulatory Standards governed by the ministerial decree (44/2000) for wastewater discharge into public sewage network to protect the environment as well as selecting the wastewater streams that need to be treated prior to its discharge to the sewer system. To achieve the required objectives, the study is conducted following some steps and approaches as evaluate the current environmental conditions in the production and service units to determine the industry required to upgrade these units in order to reduce pollution load in the final effluent. A treatability study and analysis was conducted for investigating the feasibility of each of identifying the different possible treatment trains, selecting the most suitable treatment train, and developing the basic design for the selected treatment train for the wastewater streams that need to be treated prior to its discharge to the sewer system. The results obtained show that the contamination is mainly due to the refused batches, cleaning and washing of equipment and floor. Analysis of COD and BOD during the washing and cleaning process reached 3275 mg/l and 1710 mg/l, respectively. In addition, it was noticed that the pH value fluctuated between acidic and alkaline ranges and most of the organic contents are in soluble phase.

Accordingly, a treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater streams of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques. So, the proposed treatment technique is including pollution prevention measures for the most polluted stream, primary treatment (oil separation, equalization, ph adjustment, nutrients supplement), biological degradation using activated sludge process, and tertiary treatment using granule activated carbon. Accordingly, from the study it is concluded that the biological degradation process followed by tertiary treatment using granule activated carbon is the most reliable alternative treatment method for this kind of industry. The removal efficiency reached 96.1%, 95%, 95.6%, 87.3% for Turbidity, COD, BOD, and TSS.

Keywords: *Pharmaceutical and Chemical Industry, Biological Treatment, Industrial Wastewater Treatment, Cleaner Production.*

1. Introduction

The chemical industry is of importance in terms of its impact on the environment. The wastewaters from this industry are generally strong and may contain toxic parameters. Chemical industrial wastes usually contain organic and inorganic matter in varying degrees of concentration. It contains acids, bases, toxic materials, and matter high in biological oxygen demand, color, and low in suspended solids. Many materials in the chemical industry are toxic, mutagenic, carcinogenic or simply hardly biodegradable. Surfactants, emulsifiers and petroleum hydrocarbons that are being mixed with pesticide active ingredients form emulsion with water, which reduce performance efficiency of many treatment unit operations [1]. In chemical industry, the high variability, stringent effluent permits, and extreme operating conditions define the practice of wastewater treatment. Although pharmaceutical wastewater may contain diverse refractory organic materials that cannot be readily degraded, biological treatment is still a viable choice for treatment [2, 4].

The best strategy to clean highly contaminated and toxic industrial wastewater is in general to treat them at the source [4] and sometimes by applying onsite treatment within the production lines with recycling of treated effluent [5]. Since these wastes differ from domestic sewage in general characteristics, pretreatment is required to produce an equivalent effluent [1, 6]. A proposed concept to select the appropriate treatment process for chemical industrial wastewater based on molecular size and biodegradability of the pollutants [5]. The wastewater characteristics play a key role in the selection of biological treatments. Chemical industrial wastewater can be treated by some biological oxidation method such as trickling filters, rotating biological contactor (RBC), activated sludge, or lagoons; also, coagulation is necessary for some waste [7]. Waste minimization in the production process in chemical industry is the first and most important step to avoid waste formation during the production [2, 8]. Because of the fluctuation in the strength and flow rate, Bury et al. applied dynamic simulation to chemical-industry wastewater treatment plant to manage and control the treatment plant [9]. Conventional systems that use an activated sludge process are still widely employed for wastewater treatment, mostly because they produce an acceptable quality effluent at reasonable operating and maintenance costs. But this type of treatment has limited capability of removing pharmaceuticals from wastewater [10, 11, 12]

Typically, an anaerobic process is applied to remove high concentrations of organic matter and decompose refractory substances [13, 14]. followed by an aerobic treatment to oxidize the residual organic matter in the wastewater. Since influent COD is very high in most cases, effluent from the anaerobic bioreactor can still have residual COD, which may be as high as several hundreds or even thousands of milligrams per liter, even if organic matter removal efficiency is above 90%. Therefore, direct discharge of effluent from the anaerobic bioreactor is not permitted, and post treatment of anaerobic process effluent with an aerobic bioreactor is necessary in most cases. A sequencing batch bio-filter was used as alternately operating under anaerobic and aerobic conditions to treat pharmaceutical wastewater with influent COD of 28,400 to 72,200 mg/L, achieving COD removal of 95 to 97%. In addition to organic matter degradation, both biological and abiotic degradation of some antibiotics including their pathways and products have also been documented [15]. However, most published studies investigated the removal of organic materials that were reflected as COD but ignored antibiotics in pharmaceutical wastewater treatment. Although high COD removal efficiencies could be achieved, biological treatment processes could be ineffective in the removal of antibiotics under some circumstances [16].

An experimental work conducted, indicated that the startup biological treatment of pharmaceutical wastewater was fairly quick and was achieved in about 12 days. Additionally, acceptable levels of MLSS were maintained in the reactors during a period of less than two weeks. The study revealed that the pharmaceutical wastewater was basic in nature, and was characterized by high levels of dissolved oxygen with concentrations of heavy metals well within the acceptable range for growth of microorganisms. Values of bio-kinetic coefficients obtained in this study were 1535.8 mg/L for the half velocity coefficient, 0.343 day-1 for the maximum rate of substrate utilization per unit bacterial mass, 1.15 for growth yield coefficient based on COD, and 0.027 day-1 for the decay rate coefficient [17].

Biological treatment is still regarded as the most common and economical approach for the treatment of contaminants in wastewater. High-technology and low-cost bio-units have been successfully established for the treatment of variety of organics found in wastewater of municipal and industrial origin [18]. However, activated sludge treatment was shown to degrade pharmaceuticals in extents that ranged from complete to very poor degradation. Longer sludge retention time improved degradation, but most of the investigated compounds could not be completely degraded [19]. As a result, many pharmaceuticals are only partially removed during biological processes and get released to surface waters [20]. Hence, biological wastewater treatment is insufficient for some recalcitrant pharmaceuticals, and advanced treatment processes prior to and/or after biological treatment seem promising and even necessary where pollution is present or anticipated. Numerous treatment technologies have been evaluated for this purpose, including chemical oxidation using ozone and hydroxyl radicals generating processes, membrane filtration such as nanofiltration and reverse osmosis, and activated carbon adsorption [21].

Combined Fenton-like treatment and lime coagulation were applied and optimized for three rinsing water samples from formulation of different medical ointments. Lime coagulation facilitated additional COD removal in pharmaceutical effluents. Combined treatment of pharmaceutical wastewater samples also resulted in considerable BOD7 reduction and BOD7/COD ratio increase. Under the most favorable treatment conditions, COD removal of 87%, 94% and 96% and BOD7 removal of 79%, 92% and 95% were achieved for Effluents I, II and III, respectively [22]. Given the relatively high concentration of organics in such effluents, a process train comprising chemical and biological oxidation may be technically and economically feasible. Conversely, pharmaceuticals found in the outlet of municipal WWTPs may not require immediate attention regarding pharmaceuticals removal since these streams are typically disposed of in watercourses and the sea. Nevertheless, treatment-at-source may still be a plausible option replacing conventional chlorination by an AOP induced disinfection/oxidation technique [23].

Anaerobic methods include anaerobic sludge reactors, anaerobic film reactors and anaerobic filters [24-28]. Coagulation–flocculation and flotation processes were evaluated for the pre-treatment of hospital wastewater, raw hospital wastewater as well as the effluent from the continuous coagulation plant were treated in a flotation cell. Removal of total suspended solids (TSS) during pre-treatment was very effective, reaching an average removal efficiency of 92% in the combined coagulation–flotation process. Flotation of raw wastewater led to slightly worse results compared to coagulation–flocculation, although the combined action of both improved the overall efficiency of the process. Up-flow anaerobic stage reactors (UASRs) used as a pre-treatment to activated sludge for industrial effluent have been shown to be efficient for the removal of pharmaceuticals even at high concentrations [26, 27]. A UASR fed with real pharmaceutical wastewater containing the antibiotics tylosin and avilamycin showed a high degree of COD and drug removal [26]. For a Hydraulic retention time (HRT) of 4 d, Organic loading rate (OLR) of 1.86 kg COD m^{-3}/d, COD reduction was 70-75 %, with an average of 95 % tylosin reduction; however, COD removal decreased with an increase in tylosin [26]. A hybrid Up-flow anaerobic sludge blanket reactor (USABR) which combines a UASR and anaerobic filter technology showed significant removal of COD at a much higher OLR from pharmaceutical wastewater [27]. The proposed pre-treatment strategy for hospital wastewater is useful for assimilating its conventional physico-chemical characteristics to that of municipal wastewater [29].

Several membrane types and applications were evaluated for the removal of Active pharmaceutical ingredients APIs at pilot and full scale, including microfiltration, ultra-filtration, nano-filtration, reverse osmosis, electro dialysis reversal, membrane bioreactors and combinations of membranes in series [30, 31]. However, the studies on the use of RO/NF for pharmaceutical removal is limited and most of the studies employed NF and RO membranes for tertiary treatment in wastewater recycling plant or for treating saline groundwater [32, 33]. Some studies reported higher removal efficiencies of polar and charged compounds in NF/RO processes due to interactions with membrane surfaces [34-36]. Though both NF and RO treatment shows potential as an efficient method for removing pharmaceuticals from the wastewater, the disposal of the sludge which could contain the pollutant in a more concentrated form remains.

There are a number of promising new treatments including AOPs such as oxidation, ozonation, perozonation, direct photolysis, TiO_2 photocatalysis, solar photocatalysis, Fenton reactions and ultrasonic irradiation. These significantly enhance the removal rate of pharmaceuticals from wastewaters. Comparisons among these technologies are problematic since most researchers used synthetic water rather than actual wastewater samples. Research is required in this area to improve treatment efficiencies, identify degradation compounds and to determine the cost and feasibility of full-scale applications. There is also interest in coupling AOPs with more conventional treatments such as activated carbon, which is the focus of ongoing research at Dublin City University [37, 38].

The complementary treatment methods such as membrane filtration, reverse osmosis and activated carbon are often used in conjunction with the traditional methods for treatment of industrial wastewater. Most of the literature published to date has been on the treatment of municipal wastewater. However, there is a growing body of research that looks at the presence of active pharmaceutical ingredients in industrial wastewater, the treatment of these wastewaters and the removal rates. It was concluded that the problem of pharmaceuticals in wastewaters cannot be solved merely by adopting end of pipe measures. At source measures, such as replacement of critical chemicals, reduction in raw material consumption should continue to be pursued as the top priority [39].

An anaerobic fluidized bed reactor (AFBR) containing particulate media such as granular activated carbon (GAC) that is suspended in the reactor by the upward velocity of the fluid (with recirculation flow rate 1008 L/d) is widely used to treat low strength municipal wastewater [40, 41]. Wastewater treatment is effected by a biofilm attached to the media. The AFBR is particularly effective for low strength wastewaters as it has good mass transfer characteristics and can retain a high concentration of active microorganisms without organism washout at short detention times of minutes to a few hours [42].

The two-stage AFMBR system employed for treating primary effluent of municipal wastewater at HRT of 1.28 h and OLR of 5.65, was able to produce an effluent with COD of 10 mg/L and BOD5, TSS and VSS near to zero. In addition, this system demonstrated its effectiveness for removing various groups of commonly detected pharmaceuticals with removal efficiencies more than 90%. Biological processes, sorption onto the GAC and membrane filtration could each play a role in removing these pharmaceuticals. The scouring effect of GAC fluidization in AFMBR successfully replaced the need of any other membrane fouling control process [43].

2. Statement of the environmental problem:

The Pharmaceutical and Chemical industry is committed to reducing environmental impacts of their activities, and to continuously improve their environmental performance and to meeting or exceeding the requirements of all applicable environmental laws and regulation. The results of the lab analysis of the industrial wastewater effluent show that the contamination is mainly due to the refused batches, cleaning and washing of equipment and floor. Analysis of COD and BOD during the washing and cleaning process reached 3275 mgO_2/l and 1710 mg/l respectively which are above the limits of the Egyptian Environmental Regulation (Decree 44/2000), while values of TSS, settle-able solids, phosphorous and total nitrogen are within the limits.. In addition, it was noticed that the pH value fluctuated between acidic and alkaline ranges and most of the organic contents are in soluble phase. Accordingly, the industry has to treat the wastewater prior to its discharge to the wastewater sanitary network.

3. Objectives of the Study:

The main objectives of this study to find a sustainable solution for the industrial wastewater in order to comply with the National Regulatory Standards governed by the ministerial decree (44/2000) for wastewater discharge into public sewage network to protect the environment as well as selecting the wastewater streams that need to be treated prior to its discharge to the sewer system, identifying the different possible treatment trains for the wastewater, conducting treatability analysis for investigating the feasibility of each of the identified trains, selecting the most suitable treatment train, and developing the basic design for the selected treatment train. The study is conducted through very precise characterization of the wastewater produced from the final effluent during the working shifts and application of appropriate treatment options for the end-of-pipe using different treatment techniques.

4. Materials and Methods

The audit program was carried out to monitor the environmentally damaged activities, compliance with legislation, opportunities for reductions, utilization and waste minimization strategies, effectiveness of existing management controls, potential remediation program and pollution prevention opportunities with relatively short payback periods. To achieve the required objectives, the study is conducted following some steps and approaches as evaluate the current environmental conditions in the production and service units to determine the industry required to upgrade these units in order to reduce pollution load in the final effluent, data collection including the collection of information relevant to the different activities in the industry including qualitative and quantitative estimation of solid and liquid wastes, collecting composite wastewater samples from the end-of-pipe industrial effluent, check on the compliance with national environmental regulation and legislation and description of the existing environmental situation in the industry, and studying the different approaches for pollution prevention and suggesting possible end-of-pipe treatment modules.

4.1. Description of the industry process:

The main two products of the industry are Metformine hydrochloride and olbiotamide. The industry has several production units such as tablets, capsules (e.g. revamycines, aspirin, tranquilizers, temperature control, fermented enzymes, laboratory chemicals and others), dry syrup and syrup.

4.2 Water balance and Wastewater Discharge of the industry process:

There are two wastewater drainage networks and two end-of-pipe discharge points in the industry, one for industrial wastewater and the other for the domestic wastewater. The domestic and industrial wastewater end-of pipe discharge points include wastewater discharges from process water, machine cleaning, floor washing, sanitary water, boiler make up water, and others. As for the domestic wastewater, it is mixed with the industrial wastewater prior to its discharge to the public sewer system. The industry consumes about 7200 m^3/day for domestic and industrial activities, while the overall total wastewater discharges equal 600 m^3/day from the domestic and industrial activities. The wastewater produced from the company is directly discharged without any treatment into eight nearby ponds in the desert. The following table illustrates the industrial and domestic wastewater discharges of the process.

Table 1: Industrial Wastewater Discharges of the Process

Uses	**Quantity m^3/d**
Process water, Machine cleaning,	5750
Floor washing	150
Sanitary water	80
Boiler make up water	20
others	
Total	**6000 m^3/day**

4.3 Sampling and characterization of wastewater

The main objective of the analysis is to investigate the compliance of the wastewater with the limits for discharge to the public sewer system, and in case of noncompliance identify and evaluate alternatives for management of the wastewater to reach compliance. For investigating the compliance of the discharged wastewater and identifying possible alternatives for its management, the sampling and analysis carried out for the wastewater in the industry was conducted as composite samples and analysis of the compiled industrial wastewater of the industry shifts as well as grab samples and analysis of the mixed industrial and domestic wastewater in each of the three operating shifts. The samples were collected during a period of almost three months The analyses were carried out according to the Standard Methods for Examination of Water and Wastewater **[44]** and covered pH, chemical and biological oxygen demand (COD and BOD), total dissolved and suspended solids (TDS and TSS), oil & grease, turbidity, total kjeldahl nitrogen, ammonia, total phosphorous, total hardness, sulfate, and phenol.

4.4 Treatability Study and Treatment Procedure

A treatability study and analysis was conducted for investigating the feasibility of each of identifying the different possible treatment trains, selecting the most suitable treatment train, and developing the basic design for the selected treatment train for the wastewater streams that need to be treated prior to its discharge to the sewer system. As well as treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater streams of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques using three proposed streams of techniques; primary treatment, biological degradation using activated sludge process, and tertiary treatment using granule activated carbon.

5- Results and Discussion

5.1: Characterization of Liquid Wastewater and Assessment of Compliance of Industrial Wastewater

For investigating the compliance of the discharged wastewater, the sampling and analysis carried out for the wastewater in the industry was conducted as composite samples and analysis of the industrial wastewater with and without the domestic wastewater. Analysis of the composite wastewater samples from industrial wastewater alone and end-of-pipe (municipal and industrial wastewater) are shown in following tables and figures.

Table 2: Characteristics of the Industrial Wastewater alone

Parameters	**Unit**	**Sample-1**	**Sample-2**
pH	--	4.6	4.1
Turbidity	NTU	105	71
Chemical oxygen demand	mgO2/l	3275	1370
Biological oxygen	mgO2/l	1710	480

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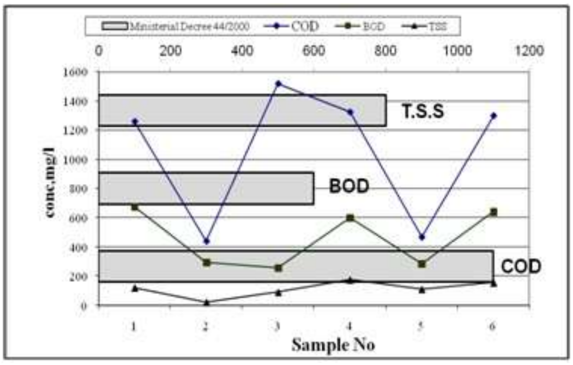
Parameters	Unit	Sample-1	Sample-2
demand			
Total suspended solids	mg/l	144	60
Total dissolved solids	mg/l	1196	1699
Total Kjeldahl nitrogen	mg N/l	44.8	19
Ammonia	mg N/l	8.9	6.7
Total phosphorous	mg P/l	1.5	2
Oil & grease and all extractable matters by chloroform	mg/l	293	123
Hydrogen sulfide	mg/l	N.D	N.D
Total hardness	mg/l	280	220
Sulfate	mg/l	117	110
Phenol	mg/l	0.03	0.25

The results obtained show that the contamination is mainly due to the refused batches, cleaning and washing of equipment and floor. Analysis of COD and BOD during the washing and cleaning process reached 3275 mgO2/l and 1710 mg/l, respectively. In addition, it was noticed that the pH value fluctuated between acidic and alkaline ranges and most of the organic contents are in soluble phase.

Table 3: Physicochemical Analysis for End-of-pipe (municipal and industrial wastewater)

Parameters	Unit	Min.	Max	Avg.
pH	--	4.3	9.3	---
Total chemical oxygen demand	mgO2/l	496	1300	734
Soluble chemical oxygen demand	mgO2/l	445	1245	646
Biological oxygen demand	mgO2/l	240	905	376
Total suspended solids	mg/l	63	156	94
Total dissolved solids	mg/l	1136	2263	1707
Total Kjeldahl nitrogen	mg N/l	17.9	142	51.4
Ammonia	mg N/l	N.D	22.4	11.7
Total phosphorous	mg P/l	0.5	4	2.8
Oil & grease and all extractable matters by chloroform	mg/l	31.2	203	84.2
Hydrogen sulfide	mg/l	N.D	12	4.2
Total hardness	mg/l	190	406	278
Sulfate	mg/l	83	197	134
Phenol	mg/l	N.D	0.4	0.18

Figure 1: Variation of Different Parameters in Final Effluent



The above results show the physico-chemical analysis of the final effluent during the first shift. Some samples were complying with the ministerial decree 44/ 2000, while others violating the limits stated in the law. The quality of wastewater produced depends primarily on the rate and type of production and market needs. It was noticed that at the end of each month, the production rate greatly decreased and it was increased by the beginning of each month (This phenomenon is confirmed in Table (3) for the samples collected during the second shift. Therefore, in order to have concrete performance and exact quality of the end-of-pipe, it was decided to collect composite samples during the three working shifts. Table (3) and Figure (1) show the variations of the quality of wastewater discharged at different time intervals. It is clear that there are great fluctuations among the concentrations of COD, BOD and TSS in the final effluent. This justifies the need for the implementation of an equalization tank prior to any treatment.

Analysis of the end-of-pipe indicated the presence of toxic materials especially the organic solvents such as n-butanol, methanol and toluene. Also, dicyandiamide, pyridine and other chemicals exist. The toxicity effect is predicted through the analysis and calculation of BOD/COD ratio which was <0.5 in some samples. These toxic materials inhibit the activity of microorganism if activated sludge process will be used for treatment of end-of-pipe. Therefore, auditing and survey of the different manufacturing processes in the company indicated that the main source of toxic materials is coming from the diabetic medicine and sulfate factory.

5-2 Treatability Study and Identification of Possible Treatment Schemes

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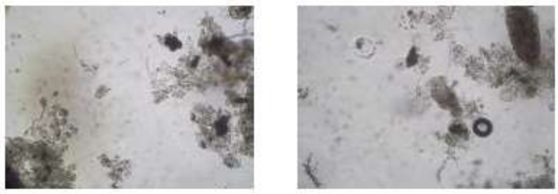
Alternatives for management and treatment of the discharged industrial wastewater to the limits of the Egyptian Environmental Regulation (Decree 44/2000) will be identified and assessed to investigate their feasibility from environmental and technical perspectives. Pollutants in the domestic wastewater are expected to be lower than that of the industrial wastewater, accordingly mixing of the industrial and domestic wastewater is expected to dilute the pollutants discharged from the industrial wastewater. According to the laboratory analysis carried out for the mixed wastewater stream, it is clear that the pollutants concentration has decreased but it is still not complying with the regulatory discharge limits.

Biological treatment using activated sludge process:

The system used is shown in Figure (3). Before starting the aerobic treatment, the chemical oxygen demand, total kjeldhal nitrogen and total phosphorous contents were analyzed to insure the C:N:P ratio and to add supplemental nutrients if needed. Nutrients requirement for aerobic treatment wastewater has to be within the reported values i.e. C: N: P ratio of 300:5:1 (based on COD concentration) for aerobic biological treatment. Also, adjustment of pH around 7 was carried out using sulfuric acid (1N) or sodium hydroxide. For the enrichment of heterotrophic and nitrifying bacteria (Nitrosomonas plus Nitrobacter), sludge from an activated sludge wastewater treatment plant was loaded into a growth column with 2.5 liters capacity. The column was operated using air pump with two outlets. The initial concentration of the mixed liquor suspended solids (MLSS) within the column was adjusted to 3 g/l. Gradual addition of wastewater to the aerated column was carried out to adapt the sludge to the wastewater. At the starting period of the treatment, the ratio of raw wastewater to sewage was adjusted to be 50:50 for a period of one week. This ratio was increased to 75:25 in the second week. Full feeding with raw wastewater was done in the third week. Adaptation of the sludge to the experimental conditions was continued for extra four weeks. During the adaptation period, COD concentration and pH values were measured. After sludge adaptation and reaching the steady state condition, a growth curve for the COD and TSS removal rates were carried out to determine the optimum detention time needed for the biological degradation.

As a conclusion, after applying the in- plant control measures, the effluent was subjected to biological treatment using activated sludge process. The activated sludge is a wastewater treatment method in which the carbonaceous organic matter of wastewater provides an energy source for the production of new cells for a mixed population of microorganisms in an aquatic aerobic environment. The microbes convert carbon into cell tissue and oxidized to produce end products that include carbon dioxide and water. The success of the activated-sludge process depends upon establishing a mixed community of microorganisms that will remove and consume organic waste material, that will aggregate and adhere in a process known as bio flocculation and that will settle in such a manner as to produce a concentrated sludge. Due to the highly contaminated wastewater with different chemicals, the adaptation of microorganism took more than four weeks.
Microscopic examination of the aerobic sludge indicated that the most dominant species adapted in this industrial wastewater are belonging to fauna, namely; Vorticella (Ciliate, Protozoa), Paramecium (Ciliate, protozoa) and Rotifers (phylum, rotatories).

Figure 2: Microscopic examination of the aerobic sludge



- *Adsorption using granule activated carbon*

For improving the quality and color of the biologically treated effluent, granule activated carbon was used as a tertiary treatment step. Figure (4) shows the column used. The column was 100 cm height with 6 cm diameter.The column was operated at flow rate of 10 ml/min . The column supported with 30 cm of gravel zone and 60 cm of granule activated carbon . The treated effluent was collected using a suction pump. Granule activated carbon was washed by conc. HCl and put in oven over night at a temperature of 160°C in order to be activated.

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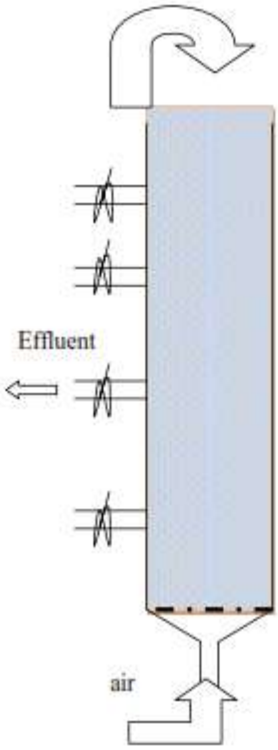

Figure 3: Activated Sludge Column

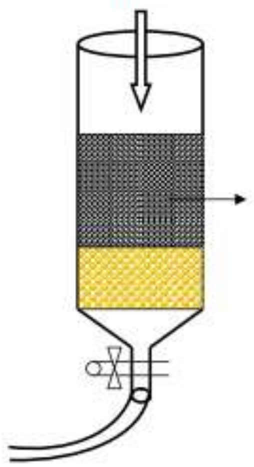

Figure 4: Activated Carbon Column

5-3 The proposed Treatment Technique:

As a results from the treatability study, the proposed treatment technique is including pollution prevention measures for the most polluted stream, primary treatment (oil separation, equalization, ph adjustment, nutrients supplement), biological degradation using activated sludge process, and tertiary treatment using granule activated carbon as shown in the following figure.

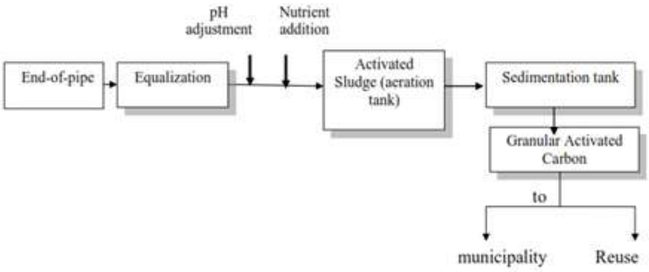

Figure 5: The Proposed Treatment Schemes

The following table illustrates the overall efficiency of treatment process .The results obtained indicated that activated sludge process followed by carbon filter produced a very satisfactory effluent which complies with all the stated parameters in the Ministerial Decree 44/2000, for wastewater discharge into public sewage network.

Table 4 : Physico-chemical Analysis and Removal Efficiency (%R) of the Treated Effluent

Parameters	Unit	Raw W.W	Biological effluent	Carbon adsorption	%R
pH	--	8.3	7.33	7.8	--
Turbidity	NTU	18.1	6.6	0.7	96.1
Total chemical oxygen demand (COD)	mgO2/l	700	78	35	95
Biological oxygen demand (BOD)	mgO2/l	372	30	16	95.6
Total Suspended Solids (TSS)	mg/l	186	72	N.D	87.3
Color	unit	224	310	20	91
Sludge Analysis					
Volume	ml/l	--	279	--	--
Organic	mg/l	--	2.8	--	--
Inorganic	mg/l	--	1.2	--	--
SVI			69.7		

5-4: The engineering design for proposed alternatives

The previous results indicated that the best process alternative is the biological degradation process followed by tertiary treatment using granule activated carbon gives best treatment efficiency of the wastewater. Accordingly, basic engineering design is conducted for this alternative. The suggested treatment sequence of the end of pipe effluent wastewater from the industry, as shown in figure 5, shall comprise the following:

Collection and Equalizing Tank: The wastewater discharge is collected in new Equalizing Tank to adsorb any fluctuations in the influent flow-rate or characteristics, so that downstream treatment plant operates at an equalized wastewater flow. It is installed with volume of 500 m3 and retention time of 2hrs to allow the influents generated from the factory to be collected and homogenized. The tank is equipped with two submersible pumps each with flow 250 m^3/hr.

Aeration Tank: The aeration tank of total volume 700 m^3 is required. The tank shall be equipped with Inlet and drainage valves and equipped with aeration system which comprise of air diffuser fine of 2.5 mg/l of dissolved oxygen in the mixed liquor.

Final Settling Tank: The settling of tank 500 m^3 in volume shall be installed with a retention time between 1-2 hrs to allow the effected settling time for the influents outflow from the aeration tank.

Granular Activated Carbon Package: Granular Activated Carbon filter compact sit of capacity 250 m^3/hr is used as a tertiary treatment step to improve the quality and color of the biologically treated effluent and remove contaminants and impurities for different applications like BOD&COD, Total suspended solids, turbidity, and removal of color, smell, and odor. An activated carbon is used to polish process water and treat wastewater utilizing chemical adsorption using powdered block filters or granular activated based upon the increased surface area of carbon.

Sludge Treatment: Sludge and scum from the settling tank shall be passed to the sludge collection sump. The sump shall be circular with volume not less than 4.5 m3. The sump shall be equipped with two submersible pumps each with flow 4.5 m^3/hr and 10m head. The sludge pumps shall be pumped the raw sludge to the dewatering system which comprise of pre-dewatering table, polymer preparation and dosing system, sludge filter press. The dewatered outlet sludge should contain a minimum of 20 – 25%. Unit shall be supplied complete sludge handling container, conveyor, control panel and all required accessories.

The proposed optimum operating conditions of proposed the treatment system is summarized in the following table.

Table 5: Optimum Operating Conditions of Proposed the Treatment System

Parameters	Results
Wastewater discharge	6000 m3/ day
Flow	250 m3/ hr
pH of Wastewater	4.8-9.6
Biological treatment	
Optimum Aeration Time	6-8 hr
Chemical Oxygen Demand	48 - 93 mg O2/l
MISS	3 - 4g/l
Sludge Volume	300 -350 ml/l
Total Sludge Weight	3 - 3.5 g/l
SVI	70-100
Carbon adsorption	
pH	7.5 -7.9
Chemical Oxygen Demand	12 - 35 mg O2/l
Biological Oxygen Demand	8.6 - 16 mg O2/l
Total Suspended Solids	3 mg/l

The following figures illustrate the basic engineering drawings for the best process alternative.

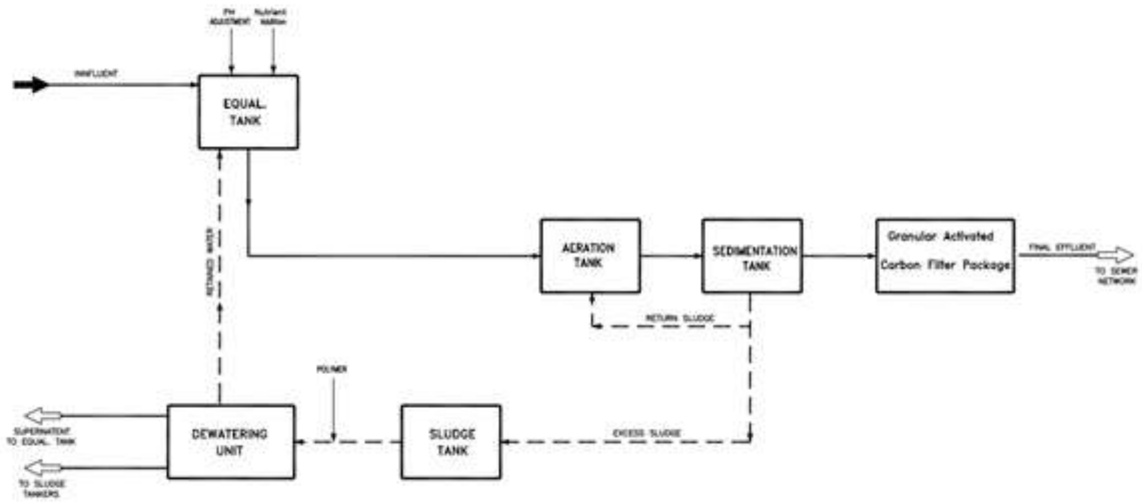

Figure 6: The process Flow Diagram of the Suggested Treatment Process

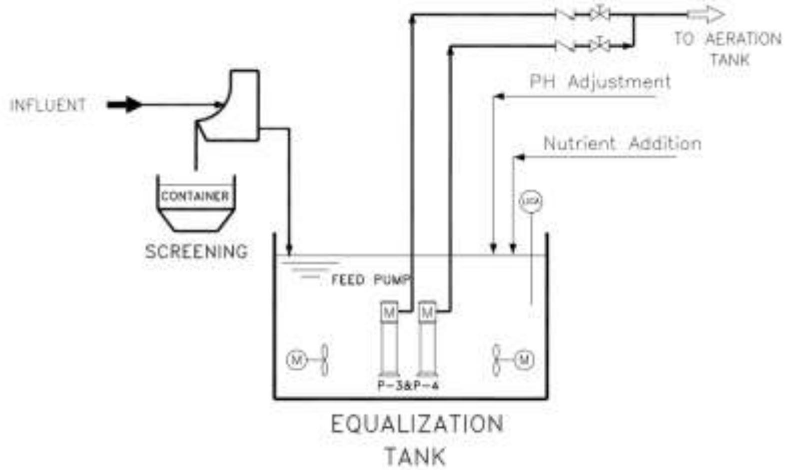

Figure 7a: The Suggested Treatment Process (Screening and Equalization) **-** Part1

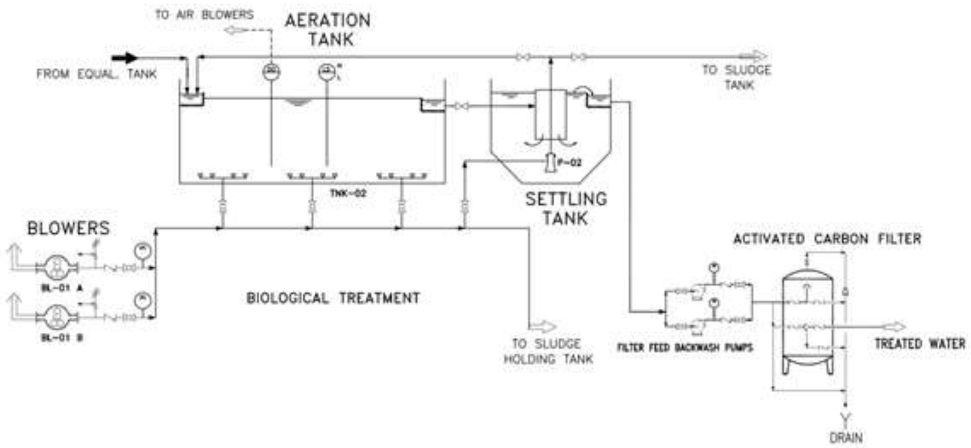

Figure 7b: The suggested Treatment Process (Biological Treatment) – Part2

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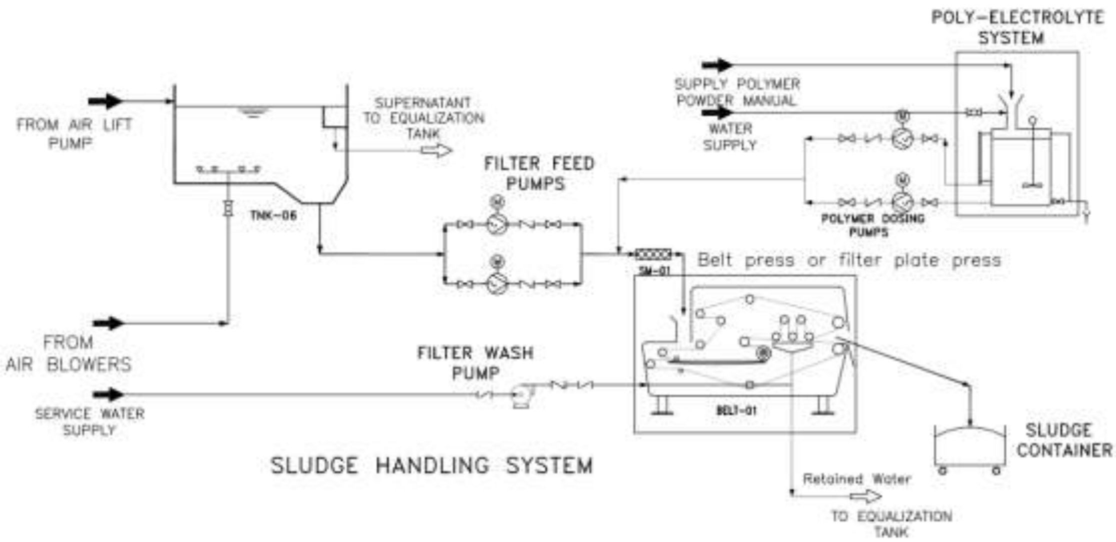

Figure 7c: The suggested Treatment Process (Sludge Handling System) – Part3

6- Conclusion and Assessment of the Treatment Alternatives

The results obtained show that the contamination is mainly due to the refused batches, cleaning and washing of equipment and floor. Analysis of COD and BOD during the washing and cleaning process reached 3275 mg/l and 1710 mg/l, respectively. In addition, it was noticed that the pH value fluctuated between acidic and alkaline ranges and most of the organic contents are in soluble phase. The above results show the physico-chemical analysis of the final effluent during the first shift. Some samples were complying with the ministerial decree 44/2000, while others violating the limits stated in the law. The quality of wastewater produced depends primarily on the rate and type of production and market needs.

A treatability study and analysis was conducted for investigating the feasibility of each of identifying the different possible treatment trains, selecting the most suitable treatment train, and developing the basic design for the selected treatment train for the wastewater streams that need to be treated prior to its discharge to the sewer system. As well as treatment procedure through a bench scale model and treatability study was developed for the industrial wastewater streams of the industry to study the analysis of waste discharges and investigate the most appropriate treatment techniques using three proposed streams of techniques; primary treatment, biological degradation using activated sludge process, and tertiary treatment using granule activated carbon.

As a results from the treatability study, the proposed treatment technique is including pollution prevention measures for the most polluted stream, primary treatment (oil separation, equalization, ph adjustment, nutrients supplement), biological degradation using activated sludge process, and tertiary treatment using granule activated carbon. Accordingly, from the study it is concluded that the biological degradation process followed by tertiary treatment using granule activated carbon is the most reliable alternative treatment method for this kind of industry. The removal efficiency reached 96.1%, 95%, 95.6%, 87.3% for Turbidity, COD, BOD, and TSS.

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